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**Metal Survey of the Marine Clam 'Pitar  
morruhana' Collected Near a Rhode  
Island (USA) Electroplating Plant**

**(U.S.) Environmental Research Lab., Narragansett, RI**

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## Metal Survey of the Marine Clam *Pitar morrhuana* Collected near a Rhode Island (USA) Electroplating Plant

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### Abstract

Benthic fauna were collected from 17 stations in mid-Narragansett Bay, Rhode Island, during September 1973 from the vicinity of the recently-closed Quonset Point electroplating facility. Despite repeated sampling, most of the 14 species of molluscs taken, including the widgeon clam *Pitar morrhuana*, were absent from stations in the immediate vicinity of plant outfalls. In general, *P. morrhuana* captured near outfall sites exhibited high moisture content and elevated body burdens of silver, cadmium, cobalt, chromium, copper, iron, manganese, nickel, lead, and zinc compared to clams of similar size from more distant stations. Observed changes in metal concentrations and moisture content of *P. morrhuana* were probably attributable to plant operations during the preceding 30 years.

### Introduction

New England, especially the state of Rhode Island, is a major center for the North American electroplating industry. However, there are no published data in the available literature on metal accumulations in marine biota or non-biological samples collected from discharge outfalls. Accordingly, we selected for investigation the U.S. Naval Air Rework Facility (NARF) located on Quonset Point, Rhode Island (Fig. 1). The electroplating section of the Quonset Point NARF consisted of about 1500 personnel and operated more or less continuously from 1942 until it was closed in the spring of 1973. During this interval of 30 years, there were no reliable data collected on rates or quantities of wastes, including metals, discharged into Narragansett Bay nor were any studies attempted to assess environmental alterations.

The present account reports on results of a survey that we conducted in autumn of 1973 on content of metals, specifically Ag, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn, in total soft tissues of adult widgeon clam, *Pitar morrhuana*, collected from 17 stations in mid-Narragansett Bay, Rhode Island; some of these stations were in the immediate vicinity of the NARF outfalls (Fig. 1). This paper is

one of a series of reports on the Quonset Point NARF, listing metal accumulations in sediments, biota, water column, and sediment interstitial waters (Eisler et al., unpublished data; and 1977), and part of a larger program initiated by our laboratory to evaluate toxicological hazards of complex wastes discharged into saline environments.

### Materials and Methods

The 17 stations in the NARF study area (Fig. 1) were sampled for benthic fauna using a Forster-anchor dredge<sup>1</sup>. This stainless-steel device selectively collects sediments to a depth of 10 cm, with a typical sample volume of 18 l. A single collection was made at all stations on 6 September 1973. Muds were washed on deck through a 2 mm stainless-steel mesh using ambient seawater; all organisms observed were removed by hand. Widgeon clams, *Pitar morrhuana*, were frozen at -20°C for 3 to 5 weeks; the remaining organisms collected were identified and archived. A second collection at each station was made on 20 September 1973; if *P. morrhuana* had been collected on 6

<sup>1</sup>Mention of a product or trade name does not necessarily constitute endorsement by the U.S. Environmental Protection Agency.

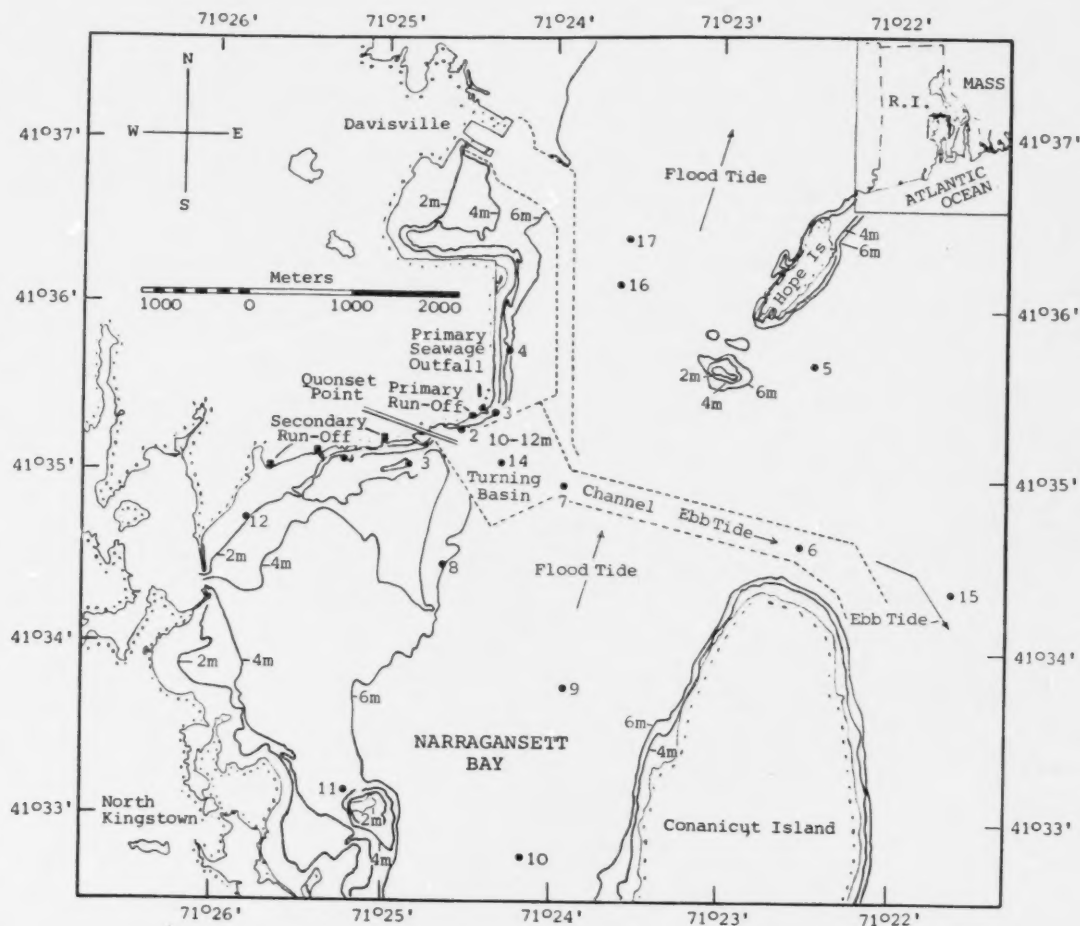


Fig. 1. Map of study area, showing station locations, hydrographic, and other features. Inset shows approximate geographic location of study area

September 1973 at a station, a single dredge sample was taken on 20 September 1973; but if *P. morrhuana* were absent from a station sample on 6 September 1973, then three dredge samples were taken from that site on 20 September. Bottom-water temperatures ranged from 18.9° to 19.1°C at all stations on 6 September and from 17.0° to 18.2°C on 20 September. Salinity values for all stations on both collection dates extended between 29.7 and 31.2‰.

For analyses, individual clams were thawed at room temperature (ca. 20°C), drained, and the total soft parts of a single clam were placed in an acid-stripped beaker; the shells were discarded. After weighing, samples were dried at 95°C for 24 h, reweighed, then ashed at 425°C for 24 h. On cooling, each sample received 10 ml of concentrated  $\text{HNO}_3$ ; it was then held at 95°C

for 24 h, and then at 425°C for an additional 24 h. Ten ml of concentrated  $\text{HNO}_3$  was added to the dried cool sample, which was then filtered through Whatman 42 paper and diluted to 50 ml with de-ionized water. Each sample was analyzed for Ag, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn using a Perkin-Elmer model 403 atomic absorption spectrophotometer and procedures outlined in the manual accompanying the instrument. Analytical precision for individual metals was within 2%, as determined by analysis of several replicates.

#### Results

A total of 30 species of benthic macro-invertebrates were collected from the 17 stations on the two sampling dates: 14 species of molluscs, 8 species of ane-

Table 1. Molluscan species collected at individual stations during Quonset Point metal survey

| Station no. | Species                                                                                                                                                                                                      |
|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1           | <i>Pitar morrhuana</i> , <i>Yoldia limatula</i> , <i>Ensis directus</i> , <i>Nassarius trivittatus</i>                                                                                                       |
| 2           | <i>N. trivittatus</i>                                                                                                                                                                                        |
| 3           | <i>Pandora gouldiana</i> , <i>Mercenaria mercenaria</i>                                                                                                                                                      |
| 4           | <i>Pitar morrhuana</i> , <i>N. trivittatus</i>                                                                                                                                                               |
| 5           | <i>P. morrhuana</i> , <i>Y. limatula</i> , <i>E. directus</i> , <i>Tellina agilis</i> , <i>M. mercenaria</i>                                                                                                 |
| 6           | <i>P. morrhuana</i>                                                                                                                                                                                          |
| 7           | <i>P. morrhuana</i> , <i>Y. limatula</i> , <i>E. directus</i>                                                                                                                                                |
| 8           | <i>P. morrhuana</i> , <i>Y. limatula</i> , <i>E. directus</i> , <i>Mya arenaria</i> , <i>N. trivittatus</i> , <i>Mercenaria mercenaria</i>                                                                   |
| 9           | <i>P. morrhuana</i> , <i>Y. limatula</i> , <i>T. agilis</i>                                                                                                                                                  |
| 10          | <i>E. directus</i> , <i>Pandora gouldiana</i>                                                                                                                                                                |
| 11          | <i>Pitar morrhuana</i> , <i>Y. limatula</i> , <i>E. directus</i> , <i>T. agilis</i> , <i>Nucula proxima</i> , <i>M. mercenaria</i>                                                                           |
| 12          | <i>Y. limatula</i> , <i>E. directus</i> , <i>Macoma balthica</i> , <i>Mulinia lateralis</i> , <i>Petricola pholadiformis</i> , <i>Solemya velum</i> , <i>Nassarius trivittatus</i> , <i>Eupleura caudata</i> |
| 13          | <i>Pitar morrhuana</i> , <i>E. directus</i> , <i>Mya arenaria</i> , <i>N. trivittatus</i>                                                                                                                    |
| 14          | <i>Y. limatula</i> , <i>Mulinia lateralis</i>                                                                                                                                                                |
| 15          | <i>P. morrhuana</i>                                                                                                                                                                                          |
| 16          | <i>P. morrhuana</i> , <i>Y. limatula</i>                                                                                                                                                                     |
| 17          | <i>P. morrhuana</i> , <i>Y. limatula</i> , <i>E. directus</i>                                                                                                                                                |

lids, 5 species of crustaceans, 2 species of nemerteans, and a single species of echinoderm. The number of molluscan species collected at any one station ranged from 1 to 8 (Table 1). A reduction in the number of molluscan species present was evident at stations in the vicinity of NARF outfalls, the turning basin and the ship channel (Fig. 2).

Despite repeated sampling, *Pitar morrhuana* was absent from collections at Stations 2, 3, 10, 12, and 14; it is noteworthy that Stations 2, 3, and 14 were located in the immediate vicinity of the NARF primary outfall.

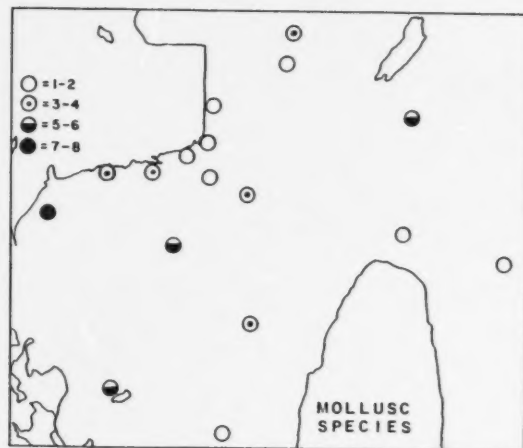


Fig. 2. Number of species of molluscs collected at individual stations (total number of molluscan species collected from all stations was 14)

Data on mean wet:dry ratios as well as concentrations of Ag, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn in *Pitar morrhuana* soft parts are shown in Table 2. When *P. morrhuana* was present, the highest mean wet:dry ratios, i.e., highest moisture contents, was observed among individuals taken at three stations near the NARF outfalls (Stations 4, 7, 16; Table 2, Fig. 3). The highest mean values recorded for all elements were, in general, confined to *P. morrhuana* collected from stations nearest the NARF outfalls (Table 2, Fig. 4). For individual *P. morrhuana*, the highest absolute values determined, in mg element per kg dry weight were: 3.3 for cadmium (Station 4); 6.6 for silver (Station 5); 6.1 for cobalt (Station 4); 17.8 for chromium (Station 8); 36.7 for copper (Station 11); 37.5 for nickel (Station 4); 78.8 for lead (Station 13); 369.0 for manganese (Station 7); 443.0 for zinc (Station 11); and 1225.0 for iron (Station 7). The implications of this will be discussed later.

It is emphasized that *Pitar morrhuana* data reported above pertain only to those clams in the size range 0.20 to 0.99 g dry weight soft parts ( $n=58$ ). For all *P. morrhuana* collected ( $n=70$ ), individual clams ranged between 0.14 and 1.80 g soft parts, on a dry weight basis. However, we found that body weight of the clams was correlated with the content of selected metals. For example, with increasing body weight of *P. morrhuana* collected from Station 11 ( $n=14$ ) we detected increasing concentrations of Mn and Zn, and decreasing concentrations of Cr and Cu. Slopes of these regressions were sig-

Table 2. *Pitar morrhuana*. Mean (standard deviation) wet:dry ratios and concentrations of 10 elements, in mg kg dry weight<sup>-1</sup>, in widgeon clam soft parts. All clams ranged between 0.20 and 0.99 g dry weight

| Station no. | No. of clams | Wet:dry       | Ag             | Cd             | Co           | Cr           | Cu             | Fe           | Mn           | Ni            | Pb             | Zn           |
|-------------|--------------|---------------|----------------|----------------|--------------|--------------|----------------|--------------|--------------|---------------|----------------|--------------|
| 1           | 1            | 11.7          | 1.16           | <0.07          | 1.9          | 8.9          | 23.3           | 489          | 41           | 14.3          | 15.1           | 145          |
| 4           | 1            | 15.2          | 3.33           | 3.33           | 6.1          | 14.2         | 2.3            | 540          | 38           | 37.5          | 13.3           | 156          |
| 5           | 7            | 11.0<br>(0.6) | 1.79<br>(0.88) | 1.41<br>(0.55) | 1.3<br>(0.7) | 7.2<br>(2.8) | 19.6<br>(2.0)  | 272<br>(66)  | 82<br>(87)   | 11.2<br>(2.0) | 11.1<br>(1.4)  | 203<br>(56)  |
| 6           | 2            | 10.8<br>(0.8) | 2.70<br>(0.52) | 2.03<br>(0.97) | 0.9<br>(0.3) | 4.4<br>(0.8) | 21.3<br>(8.2)  | 250<br>(96)  | 51<br>(29)   | 7.4<br>(0.5)  | 15.7<br>(2.0)  | 181<br>(21)  |
| 7           | 3            | 15.7<br>(2.5) | 4.64<br>(2.21) | 3.19<br>(2.02) | 2.3<br>(2.0) | 8.0<br>(2.0) | 29.6<br>(4.4)  | 799<br>(500) | 159<br>(181) | 9.8<br>(2.6)  | 25.6<br>(11.3) | 276<br>(128) |
| 8           | 6            | 13.5<br>(1.9) | 1.87<br>(0.71) | 3.02<br>(0.81) | 3.0<br>(2.6) | 7.7<br>(5.0) | 19.4<br>(4.0)  | 265<br>(68)  | 54<br>(45)   | 13.3<br>(3.7) | 16.9<br>(3.9)  | 208<br>(118) |
| 9           | 9            | 13.1<br>(2.1) | 1.67<br>(0.46) | 2.78<br>(0.69) | 0.9<br>(0.5) | 3.1<br>(1.2) | 17.1<br>(3.5)  | 393<br>(115) | 87<br>(35)   | 14.0<br>(4.8) | 19.2<br>(8.5)  | 256<br>(80)  |
| 11          | 8            | 12.9<br>(1.2) | 1.60<br>(0.29) | 2.50<br>(0.47) | 1.7<br>(1.9) | 4.6<br>(0.6) | 27.9<br>(14.9) | 214<br>(64)  | 51<br>(64)   | 10.1<br>(1.9) | 17.4<br>(3.2)  | 185<br>(109) |
| 13          | 11           | 14.2<br>(1.5) | 1.63<br>(0.43) | 2.53<br>(1.02) | 2.7<br>(1.4) | 7.2<br>(1.4) | 17.7<br>(5.1)  | 349<br>(84)  | 70<br>(33)   | 10.1<br>(3.7) | 29.4<br>(16.9) | 200<br>(84)  |
| 15          | 1            | 11.5          | 3.20           | 1.68           | 0.6          | 4.8          | 23.1           | 418          | 86           | 11.5          | 18.3           | 245          |
| 16          | 5            | 14.6<br>(1.5) | 1.87<br>(1.09) | 3.21<br>(1.16) | 1.2<br>(0.9) | 3.5<br>(0.8) | 12.8<br>(3.9)  | 449<br>(161) | 65<br>(44)   | 11.6<br>(4.5) | 26.8<br>(7.8)  | 173<br>(38)  |
| 17          | 4            | 13.2<br>(2.2) | 2.59<br>(1.51) | 1.36<br>(0.73) | 1.9<br>(1.2) | 6.2<br>(0.7) | 19.4<br>(6.3)  | 346<br>(156) | 63<br>(19)   | 13.1<br>(4.3) | 25.6<br>(16.9) | 180<br>(15)  |

nificantly different from zero at the 0.05 level. Identical trends were observed at other stations, but these were not statistically significant at the 0.05 level owing to limited numbers of *P. morrhuana* available. Elimination of all clams less than 0.20 g and more than 0.99 g dry weight from Station 11 produced slopes not significantly different from zero at the 0.05 probability level for Mn, Zn, Cr and Cu. Accordingly, data from 12 clams (6 from Station 11, and a total of 6 from other stations), all with body weights outside the 0.20 to 0.99 g range, were eliminated from Table 2 and Fig. 4.

#### Discussion

Changes in elemental composition of marine bivalve molluscs with increasing body weight, in addition to those re-

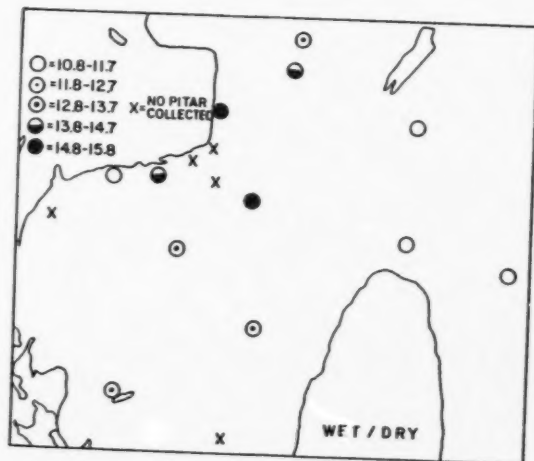


Fig. 3. *Pitar morrhuana*. Mean wet:dry ratios of clams collected from individual stations. No *P. morrhuana* were collected at stations marked X

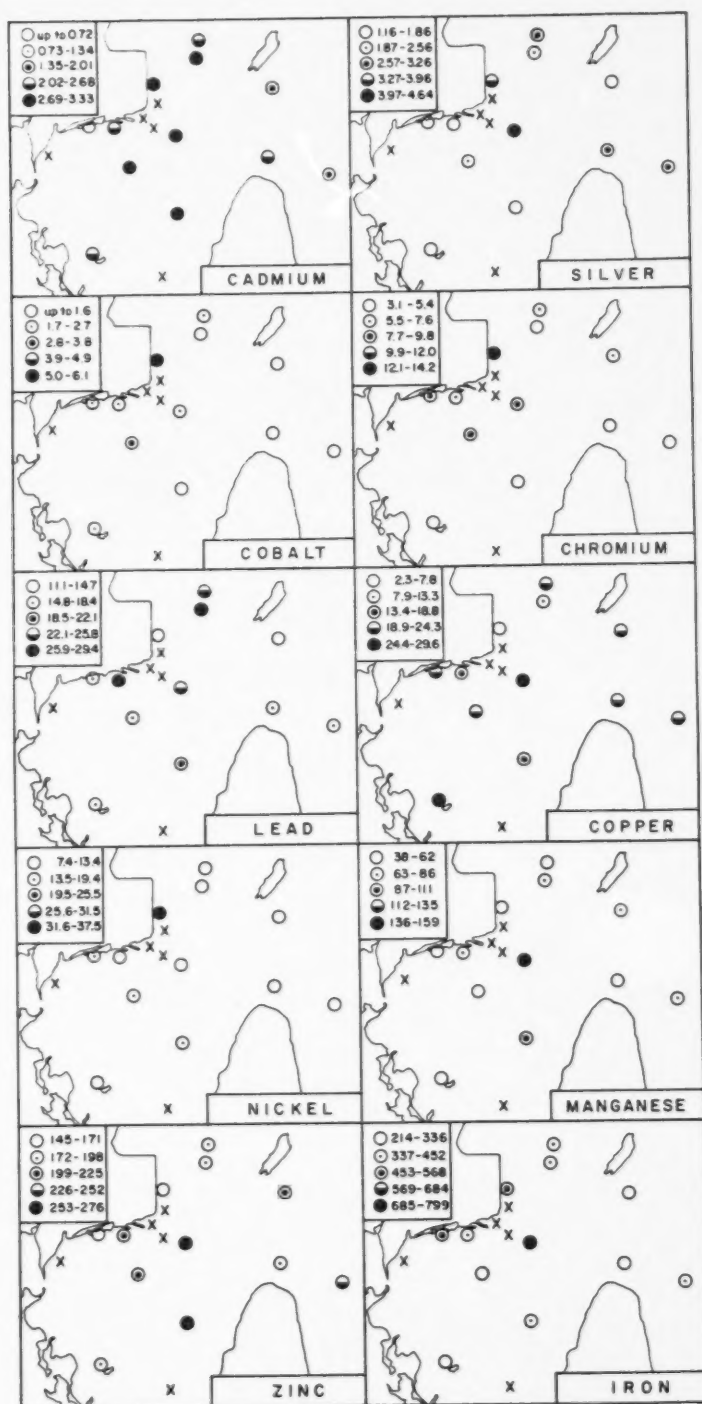


Fig. 4. *Pitar morrhuana*. Concentrations of 10 elements in widgeon clams from stations in NARF study area. Values shown are in mg element per kg dry weight soft parts, as determined by atomic absorption spectrophotometry. No *P. morrhuana* were collected at stations marked X

ported herein for *Pitar morrhuana*, have been observed for *Saccostrea cucullata* (Mackay et al., 1975), and also for *Mytilus edulis*, *Mercenaria mercenaria* and *Venerupis decussata* (Boyden, 1974). Increasing zinc content with increasing body weight was noted for *P. morrhuana* (this study) and for *Mytilus edulis* (Boyden, 1974). Decreasing copper content with increasing body weight is documented for *P. morrhuana* (this study) and for *S. cucullata* (Mackay et al., 1975); however, copper was positively correlated with increasing body weight for *Mytilus edulis*, *Mercenaria mercenaria* and *V. decussata* (Boyden, 1974). These observations demonstrate clearly that age (body weight) of *P. morrhuana*, and probably other species of bivalves, must be taken into account in future surveys involving metal residues, especially when meaningful inter-station comparisons are desired.

Concentrations of Ag, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn in *Pitar morrhuana* collected from individual stations within the NARF study area during autumn 1973 were not significantly correlated with concentrations of these same 10 elements during autumn 1973 in sediment interstitial waters or in the water column at the same stations (Eisler et al., unpublished data). However, concentrations in *P. morrhuana* of Mn and Zn, but not other metals examined, were positively correlated at the 0.05 probability level with Mn and Zn levels, respectively, in surficial sediments (Eisler et al., 1977). This finding suggests that metal accumulation mechanisms in *P. morrhuana* only partially reflect the metal composition of the immediate geochemical substrate. Because metal biomagnification via the food chain is a well-documented phenomenon in filter-feeding bivalves (Eisler, 1973; Eisler and Wapner, 1975), it is probable that future investigations will reveal that food-chain amplification may account for a major portion of the variability observed in the metal contents of *P. morrhuana* reported herein.

From a public health viewpoint, concentrations of metals in seafoods should not exceed 2 mg of lead per kg wet weight, 2 mg of cadmium, 30 mg of copper, or 1000 mg of zinc, according to the Australian National Health and Medical Research Council (ANHMRC) (as quoted in Mackay et al., 1975). On this basis, no *Pitar morrhuana* exceeded the ANHMRC recommended values for Cd, Cu or Zn. However, 12 of the 70 *P. morrhuana* collected, or about 17%, surpassed the ANHMRC recommendation for lead (Table 3). The high Pb group included small clams weighing less than 0.20 g dry weight, as well as larger ones weighing more than 0.99 g

Table 3. *Pitar morrhuana*. Lead in soft tissues of selected clams collected from mid-Narragansett Bay in autumn 1973

| Dry weight (g) | Station no. | Lead (mg kg wet weight <sup>-1</sup> ) |
|----------------|-------------|----------------------------------------|
| 1.26           | 6           | 2.1                                    |
| 0.25           | 13          | 2.1                                    |
| 0.95           | 16          | 2.2                                    |
| 1.02           | 9           | 2.2                                    |
| 0.92           | 16          | 2.3                                    |
| 0.18           | 11          | 2.4                                    |
| 0.20           | 13          | 2.8                                    |
| 0.93           | 9           | 2.8                                    |
| 1.39           | 6           | 2.8                                    |
| 1.55           | 5           | 3.2                                    |
| 0.42           | 17          | 3.9                                    |
| 0.33           | 13          | 5.6                                    |

dry weight, and represented a comparatively large number of stations in the study area (Table 3). From these data it would appear that NARF outfalls were not the sole sources of lead to *P. morrhuana*. Future studies may demonstrate that the relatively large cluster of electroplating plants discharging wastes into upper Narragansett Bay, about 20 km north of the Quonset Point NARF, may exert measurable influence on availability of lead and other metals to benthic fauna of mid-Narragansett Bay.

It was difficult to determine if the absence of *Pitar morrhuana* and other molluscan species from stations in the immediate vicinity of NARF outfalls were influenced by sediment types, maintenance dredging of the area, the discharge of wastes, or a combination of these and other factors. However, 8 species of annelids that we collected during this survey: *Nephtys incisca*, *Glycera dibranchiata*, *Ninoe nigripes*, *Pectinaria gouldi*, *Maldanopsis elongata*, *Clymenella forquata*, *Leanira hystricus*, and *Pherusa affinis* were also scarce or absent at NARF outfall stations compared to more distant locations within the study area. We concluded that the elevated concentrations of Ag, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn in *Pitar morrhuana* reported herein were probably attributable to long-term operation of the Quonset Point NARF. Because the chemical composition of NARF wastes was unknown, we were unable to determine if the metal concentrations in *P. morrhuana* were direct functions of NARF waste constituents or whether observed effects were produced

indirectly. Examples of the latter include changes in elemental composition of marine clams during exposure to insecticides (Eisler and Weinstein, 1967), metal enhancement in oysters which reflect patterns of metal contamination in sediments (Frazier, 1976), and changes in heavy metal content of oysters with seasonal variations (Frazier, 1975). Similar regulatory mechanisms may exist in *P. morrhuana*, and these could have been affected by NARF effluents. Other factors which tend to implicate the Quonset Point NARF as a source of environmental alteration include the comparatively high levels of all metals examined in surficial sediments near the NARF outfalls (Eisler et al., 1977) and the relatively high moisture content of *P. morrhuana* collected near the NARF outfalls.

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